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Relationship of Mediterranean type lamproites to large shoshonite volcanoes, Miocene of Lesbos, NE Aegean Sea

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ABSTRACT

Shoshonites, which are high-K trachyandesitic rocks, are found in many orogenic belts and are commonly of post-collisional origin. The petrogenesis of shoshonites has been widely debated. Small lava flows and dykes of lamproite and related lamproitic rocks of early Miocene age in Lesbos are coeval with voluminous shoshonite volcanoes. Their distinctive petrology and isotope geochemistry provide an exceptional opportunity to assess the petrogenetic relationship between lamproites and shoshonites. The lamproitic rocks contain phenocrysts of forsteritic olivine (as high as Fo_{93}) and clinopyroxene, both with inclusions of chrome spinel (Cr# ~0.9 or ~0.6) and carbonate melt inclusions, indicating the presence of carbonatite melts. Some complexly zoned clinopyroxene from lamproitic rocks have salite cores with chemical composition suggesting they formed in the upper mantle in a melt strongly enriched in LILE and LREE. Both lamproites and shoshonites show continuous trends of trace elements and their isotopic compositions overlap. Lack of variation in K with Mg# or SiO_2 for particular temporal–spatial groups of shoshonites suggests derivation from particular inhomogeneous mantle rather than fractionation processes. In contrast to other peri-Mediterranean lamproites, the Lesbos lamproites and shoshonites have unusual Pb isotope composition that requires a common origin from subcontinental lithospheric mantle enriched in LILE in the Paleozoic. This enrichment process involved partial melting of subducted carbonate-bearing pelites. Triassic rift-related volcanism and formation of Jurassic small ocean basins produced extreme depletion of parts of the mantle. Lamproitic magma was derived from melting of enriched refractory harzburgite, whereas enriched lherzolite, wehrlite and pyroxenite partially melted to supply larger volumes of shoshonitic and related magmas. The NE Aegean Miocene shoshonite province is thus not directly related to contemporary subduction, but may have been triggered by related back-arc extension.

1. Introduction

Shoshonites, which are potassium-rich trachyandesites, are found in many orogenic belts and are commonly of post-collisional origin. They show many geochemical features of subduction-related calc-alkaline rocks, except for greater enrichment in K, LILE and other incompatible trace elements. They are generally erupted as large stratovolcanoes. The type shoshonite locality is the Absaroka volcanic province of Wyoming (Feeley, 2003), but they have been recognised in many orogens (e.g., Blatter et al., 2001; Kay and Kay, 1993; Lipman et al., 1971; Manley et al., 2000; Seghedi et al., 2004). Most authors identify subcontinental lithospheric mantle or asthenospheric mantle, both previously enriched in incompatible elements by earlier subduction, as the principal source of both shoshonitic and associated calc-alkaline magmas (Aldanmaz et al., 2000; Seghedi et al., 2004). Some have argued that shoshonites result from active subduction (Blatter et al., 2001; Bonev and Beccaletto, 2007), although most authors regard shoshonites as post-collisional and related to the thermal effects of mantle processes such as slab break-off or lower-crustal delamination (Aldanmaz et al., 2000; Kay and Kay, 1993; Pe-Piper and Piper, 2007a). Others have emphasized magma fractionation and crustal assimilation as the dominant processes influencing the eruptive character of both shoshonites and associated calc-alkaline rocks (Feeley and Cosca, 2003; Meen, 1987).

Potassic post-collisional volcanic rocks are varied and widespread following the alpine orogeny of the Mediterranean region, including the varied rocks of the Roman province (Pecerillo, 2005) and widespread minor trachytic rocks in the Aegean Sea (Ersoy and Palmer, 2013; Pe-Piper and Piper, 2006) and adjacent southwestern Anatolia (Prelević et al., 2012; Seghedi et al., 2013). The potassic rocks also include the early Miocene shoshonitic province of the northeastern Aegean Sea and adjacent northwestern Anatolia (Altunkaynak and Dilek, 2006; Pe-Piper and Piper, 2002; Pe-Piper et al., 2009). This large and well-known development of shoshonitic rocks includes the Lesbos volcanic centre, representing more than 100 km^3 of volcanic products. Lamproites are also a minor but widespread feature of post-collisional

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volcanism in the peri-Mediterranean region, occurring as rare, metre-sized dykes and remnants of lava flows (Prelević and Foley, 2007; Prelević et al., 2005, 2007, 2012).

In this paper we report for the first time the occurrence of coeval lamproites and rocks of lamproitic affinity rocks from the shoshonitic volcanic centre of Lesbos, Greece (Fig. 1). This is not just an account of another geographic locality of peri-Mediterranean lamproites. The Lesbos lamproitic rocks are unusual in having Pb-isotope compositions that imply a Paleozoic or older mantle enrichment event, in contrast to the apparent Mesozoic–Cenozoic enrichment of most peri-Mediterranean lamproites (Tommasini et al., 2011). In addition, the mineralogy and geochemistry of lamproites and the coeval voluminous shoshonites of the Lesbos volcanic centres provides evidence for their close genetic relationship. In this paper, we first present the mineral textures and chemistry and the whole rock composition of the lamproitic rocks. Based on these results, we then demonstrate the relationship between lamproites and shoshonites in Lesbos and show its more general applicability to the entire NE Aegean shoshonite province.

2. Geological setting

2.1. Regional geology and volcanic stratigraphy of Lesbos

The geological history of Greece and adjacent areas of the eastern Mediterranean is related to the margins of Gondwana. Basement gneisses in the Menderes massif and Ios record the late Neoproterozoic Pan-African orogeny (Pe-Piper and Piper, 2002, Ch. 2). There is little rock record in Greece of the spreading and subduction of the Rheic (Nance and Linnemann, 2008) and Paleotethyan oceans (Stampfli, 2000), but the final collisional product is recorded in Variscan paragneisses and granites underlying wide areas of Greece (Pe-Piper and Piper, 2002, Ch. 2). The paragneisses include metavolcanic rocks of ophiolite and subduction origin, documenting a full oceanic history. The Variscide collisional orogen rifted apart in the Triassic, producing several microcontinents of Gondwanan affinity, separated by strands of the Neotethys ocean. Seafloor spreading continued throughout the Mesozoic, followed by major collision in the Paleogene. The main Neotethyan ocean appears to have subducted beneath northern Neotethys and the southern European margin since at least the Cretaceous (van Hinsbergen et al., 2005). Subduction along the southern margin of Anatolia, including Cyprus, largely ended in the early Miocene, but subduction has continued since then at the southern margin of the Aegean microplate with major roll-back (Jolivet et al., 2013).

The island of Lesbos has a thick sequence of Miocene volcanic rocks (Figs. 1, 2). These rocks form stratovolcanoes that extend SW–NE across the centre of the island and have felsic pyroclastic rocks onlapping metamorphic basement on their flanks. The earliest (21.5 Ma) volcanism (Eressos Formation) was principally of calc-alkaline geochemical character (Fig. 2). It was followed by intense volcanic activity between 18.5 and 17 Ma (Pe-Piper and Piper, 1992), which erupted principally shoshonitic lavas with minor interbedded calc-alkaline andesites, assigned to the Skoutaros, Skalohorion and Sykaminea formations, based on observed superposition of lavas. A series of coeval felsic pyroclastic rocks, assigned to the Acid Volcanic Unit (Fig. 2), includes thick unwelded felsic tuffs (Sigri Pyroclastic Formation) in the western part of the island that coarsen towards a caldera at Vatoussa (Pe-Piper, 1978). The Sigri Formation is overlain stratigraphically by ignimbrites (Polychnitos Ignimbrite Formation) derived from a caldera in the north of the island near Lepetimnos (Pe-Piper, 1978) (Fig. 1B). Basaltic dykes and small flows in southeastern Lesbos, near the town of Mytilene (Mytilene Basalt Formation), are young on the basis of stratigraphic position and a radiometric date of 16.8 ± 0.9 Ma (Borsi et al., 1972; Pe-Piper and Piper, 1993). Minor mafic lavas and dykes in southeastern Lesbos at Agios Nektarios (Pe-Piper et al., 2003) and related felsic pyroclastic rocks yielded ages (respectively 17.9 ± 0.5 Ma K/Ar whole rock; 18.1 ± 0.3 Ma $^{40}Ar/^{39}Ar$ on biotite) that suggest that they are coeval with the Skoutaros Formation and Acid Volcanic Unit. The Agios

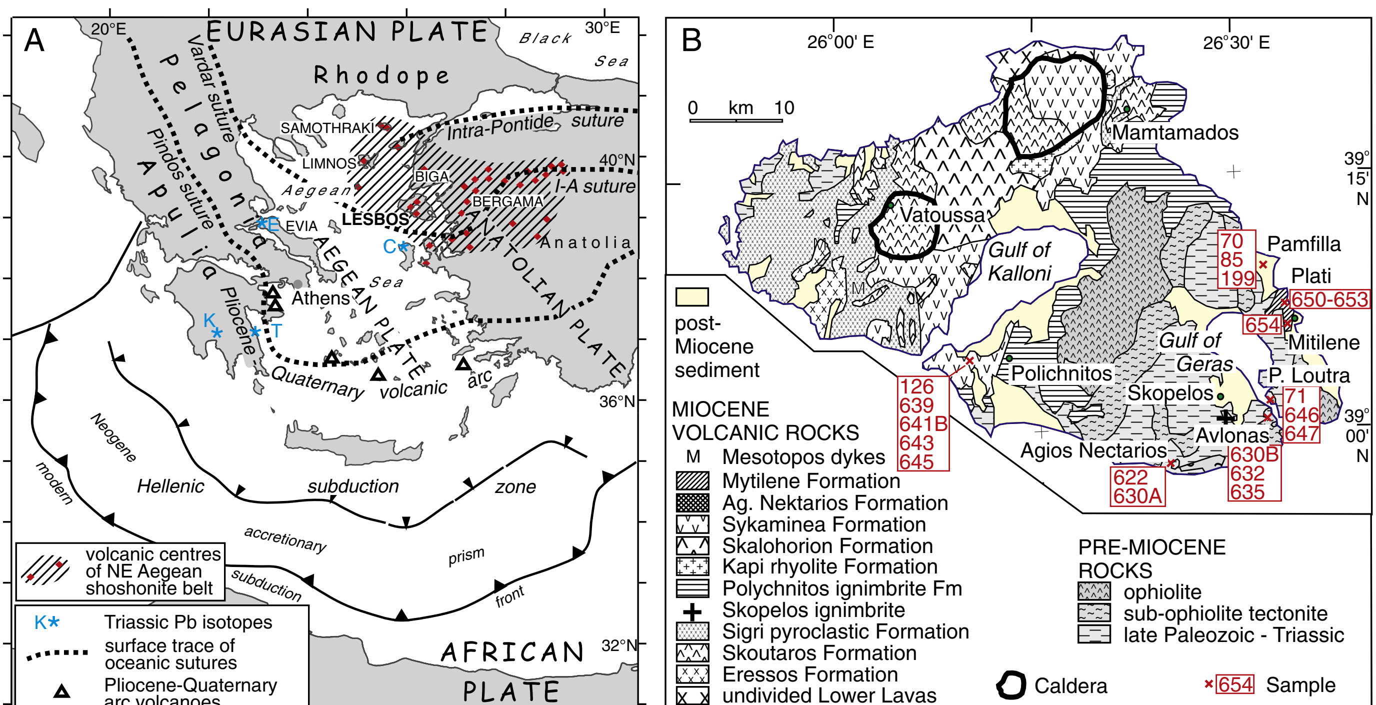

Fig. 1. (A) Regional map of the Aegean region showing the tectonic setting of Lesbos and the Northeast Aegean shoshonite province. I–A = Ankara–Izmir suture. Pb isotopes on Triassic volcanic rocks from C = Chios, E = Edipsos, K = Kalamae, and T = Tyros (Pe-Piper, 1998). (B) Geological map of Lesbos (modified from Pe-Piper and Piper, 1992) showing location of key samples.